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# End Tidal Carbon Dioxide ($EtCO_2$) Measurement in Newborns (When?, Where? and How?)

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Respiratory diseases in newborns are common clinical problems, especially in preterm infants. Formerly, the only method to evaluate the adequacy of ventilation and oxygenation was by assessment of arterial blood gas (ABG) in these patients. ABG, which is a painful and time consuming procedure, provides intermittent, not continuous data, that limits its use in documenting transient events. Therefore, noninvasive systems such as pulse oximetry to determine oxygenation, and transcutaneous carbon dioxide ($PtcCO_2$) monitoring and end-tidal $CO_2$ ($EtCO_2$) measurement to evaluate the $CO_2$ status of critically ill neonates have become increasingly popular. The $EtCO_2$ monitoring has some clear advantages over the transcutaneous $CO_2$ monitoring, such as a much faster response time to changes in blood $CO_2$ levels, internal calibrating ability and no thermal injury to the fragile skin of the newborn.

$EtCO_2$ measurement is based on the principle that $CO_2$ will be detected during expiration from a correctly placed endotracheal tube (ETT). $EtCO_2$ can be detected by capnography, capnometry or colorimetric devices. The presence of $EtCO_2$ was detected significantly quicker by a capnograph than the time to reach the $EtCO_2$ level when a colour change would be first observed using a colorimetric device. Besides, contamination of colorimetric device with gastric fluid, surfactant or medications such as atropine and epinephrine can lead to false-positive results. Capnography is done by either side stream or main stream gas sampling; low flow capnography with side stream (Microstream) technology is the preferred system in NICU. A diagram of a normal capnogram is seen in Fig. 1. Most neonatal studies have shown a good correlation between $EtCO_2$ and $PaCO_2$ (r=0.8), even in preterm infants. This correlation falls with significant respiratory failure. In conjunction with ABG analysis, capnography can provide valuable information about ventilation/perfusion (V/Q) disturbances of the lung.

**Normal Capnogram (**Fig. 1)

Phase I (inspiratory baseline) reflects inspired gas, which is normally devoid of carbon dioxide

Phase II (expiratory upstroke) a rapid rise in $CO_2$ concentration as anatomical dead space is replaced with alveolar gas

Phase III is the alveolar plateau. $PCO_2$ of the last alveolar gas sampled at the airway opening is called the $EtCO_2$

Phase 0 is the inspiratory downstroke, the beginning of the next inspiration

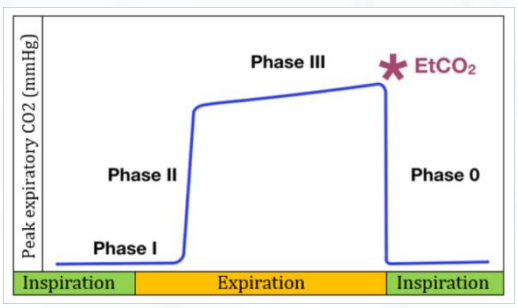


Fig. 1: Diagram of a normal capnogram that includes the inspiratory and expiratory phase (Ref. 1).

## Indications for Use of End-Tidal $CO_2$ Monitoring

-To confirm correct ETT placement: One of the most common causes of neonatal intubation failure is inadvertent oesophageal intubation, which can have catastrophic consequences. The mostly used methods of correct placement of ETT include chest wall rise with inflations, auscultation of air entry, the appearance of condensation in the tube during expiration and improvements in oxygen saturation, colour and heart rate. Some of these signs, are subjective. The addition of $CO_2$ detection using the colorimetric device is a very useful adjunct to clinical assessment; with an oesophageal tube little or no $CO_2$ is present. However, 'good $EtCO_2$ reading' does not give good information about the exact position of the endotracheal tube in the airway, i.e. an ETT could be too high or low (main stem bronchus) with an acceptable $EtCO_2$.

-During transport from secondary to tertiary care centers: Due to the nature of transport, inadvertent extubation may occur at any point enroute. The noisy environments of the ambulance or helicopter makes evaluation of ETT position difficult. Continuous use of portable $CO_2$ monitors during transport would provide an effective visual check of ETT position and effectively reassure team members. Further, it indirectly confirms ventilation and circulation.

-Integrity of ventilation: Capnography can identify disconnections in the ventilatory circuit instantaneously before $O_2$ and $CO_2$ levels change in the blood. During the course of IPPV in infants with no spontaneous breathing, $EtCO_2$ falls to zero instantaneously following the disconnections in the circuit and sounds an alarm. Corrective measures can be instituted immediately before irreversible damage is caused by prolonged hypoxia.

-Occlusion and displacement of ETT: Capnography can detect a total occlusion or accidental extubation. Total occlusion or displacement of ETT produces loss of $CO_2$ waveform in capnography. Ventilation through partially kinked or obstructed tube produces distortions in $CO_2$ waveform (prolonged phase II and steeper phase III, and irregular height of the $CO_2$ tracings.

-Apnea monitor**:** Accurate information about the rate and rhythm of respiration can be obtained by sampling $CO_2$ from respired gases using nasal adaptors. During apnea of either type, the $CO_2$ concentration at the sampling site falls rapidly and can be instantaneously detected by capnography. Therefore $CO_2$ monitoring serves as a reliable apnea monitor in neonates.

-Non-invasive monitoring of the arterial $PaCO_2$: In infants breathing spontaneously, the $EtCO_2$ values range from 36-40 mmHg. Normally $EtCO_2$, as sampled from the nasal cavity in neonates, with healthy lungs breathing spontaneously is a good estimate of $PaCO_2$. The (arterial-endotracheal; a-ET) $PCO_2$ gradient can vary from - 0.65 mmHg to 2.4 mmHg. In preterm infants the gradient may be 3.5 mmHg. Alveolar hypoventilation increases $PaCO_2$ as well as $EtCO_2$. Capnography also serves as a useful device to monitor $PaCO_2$ during mechanical ventilation of intubated neonates. It is prudent to establish the relationship of $EtCO_2$ to $PaCO_2$ initially by blood gas analysis. Thereafter, changes in $PaCO_2$ may be assumed to occur in parallel with those in $EtCO_2$ thus avoiding repeated ABG's.

-Weaning: Capnography can be used to evaluate the trend of $PaCO_2$, breathing pattern, and importantly the consistency of breathing before extubation. Ventilator rates can be gradually decreased to the lowest point at which the patient can comfortably breathe and maintain adequate alveolar ventilation.

-To demonstrate return of spontaneous circulation (ROSC) during cardiac arrest: During cardiac arrest, circulation ceases and $EtCO_2$ gradually disappears, reappearing only when circulation is restored either by effective cardiopulmonary resuscitation or cardiac function. During cardiopulmonary resuscitation, a positive test confirms placement of the ETT within the airway, whereas a negative test indicates either oesophageal placement or airway intubation with poor or absent pulmonary blood flow.

-Monitoring the course of Pulmonary Disease: In neonates with respiratory disease, the (a-Et)$PCO_2$ difference becomes wider, as for example, in infants with bronchopulmonary

dysplasia (BPD), where the gradient may be as much as 9 mmHg. The (a-Et)$PCO_2$ gradient has been used to assess the effectiveness of diuretic therapy in the improvement in V/Q status of the lung in infants with BPD. The gradient may also be used to assess the improvement in lung function following surfactant therapy in newborns with respiratory distress syndrome (RDS). The shape of capnogram also gives information about V/Q status of the lung. Increased V/Q mismatch is suggested by an increase in the slope of phase III.

Physiological and technical limitations of capnography in newborns:

In newborns, the short exhalation times, low tidal volumes and high impact of apparatus dead space hamper $EtCO_2$ measurements. Newborns require faster $CO_2$ sensors and low suction flow for side stream measurements. In addition, $EtCO_2$ is not feasible in high-frequency oscillators or jet ventilators as the volume of each breath is less than dead space. The interpretations of $EtCO_2$ values may be challenging in infants with cardiac anomalies, pulmonary hypoperfusion, myocardial dysfunction, or hypoxaemia after asphyxia. False negative results may also occur in severely hypocarbic neonates especially those weighing <1 kg. Many NICUs utilize $PtcCO_2$ as a primary means of $PaCO_2$ monitoring. Finally, the widespread acceptance of capnography for neonates requires new, well designed studies to demonstrate its clinical value and various diagnostic possibilities in these patients.

***References:***


1- Aminiahidashti *H et al. Applications of End-Tidal Carbon Dioxide (ETCO2) Monitoring in Emergency Department; a Narrative Review.* Emerg (Tehran). 2018; 6(1): e5.

2- Selby ST *An Update on* End-Tidal *CO2* Monitoring. Pediatr Emerg Care. *2018 Dec;34(12):888-892.*

3- *Scrivens A et al.* Is waveform capnography reliable in neonates? *Arch Dis Child. 2019 Jul;104(7):711-715.*

4- *Lin HJ et al.* End-tidal carbon dioxide measurement in preterm infants with low birth weight. *PLoS One. 2017 Oct 17;12(10):e0186408.*